

SOLARMAX/Electron Pitch Angle

Anisotropy Distributions

Summary Final Research Report

NASA Grant NAG5-9646

by

David L. McKenzie, Principal Investigator,
and

Phillip C. Anderson
Space Science Applications Laboratory
Laboratory Operations
The Aerospace Corporation
El Segundo, CA 90245

March 20, 2002

This work was supported by the National Aeronautics and Space Administration
under Grant NAG5-9646

SOLARMAX/Electron Pitch Angle Anisotropy Distributions
Summary Final Research Report
NASA Grant NAG5-9646

This report summarizes the scientific work performed by The Aerospace Corporation under NASA Grant NAG5-9646, titled "SOLARMAX/Electron Pitch Angle Anisotropy Distributions." The period of performance for the Grant was June 1, 2000 to December 31, 2001.

Anderson, Petrinec, and Liou [2001] studied statistical patterns in auroral emissions observed by the UVI and PIXIE instruments on *Polar* and by electron detectors aboard the *NOAA* and *DMSP* spacecraft. Statistical auroral ovals were compiled for the UVI Lyman-Birge-Hopfield short- and long-wavelength bands (LBHS and LBHL), PIXIE (X rays > 2 keV), and the *NOAA* and *DMSP* particle detectors. The PIXIE ovals were separately binned by the Dst and Kp indices. The results showed that there were no significant differences, other than intensity, in the ovals when they were binned by Kp, but that the magnetic-local-time (MLT) distributions of auroral X rays were well correlated with variations in Dst.

The UV images showed emission peaks in the afternoon sector that were completely absent in the PIXIE images and in the *NOAA* medium-energy electron distributions. In addition, the *DMSP* statistical ovals showed electron energy flux peaks in the dusk sector, also absent in the X-ray images. These emissions were probably due to accelerated electrons with characteristic energies below 1 keV. In the premidnight sector, PIXIE saw an emission maximum coincident with the UVI maximum at times when $Dst > 0$. These emissions were attributed to the substorm surge and intense fluxes of accelerated electrons above a few keV.

The X-ray emissions moved downward and equatorward during times of increasingly negative Dst. The dawnside peaks in the UVI and PIXIE images resulted from hot plasma-sheet electrons drifting around from the nightside; the flux and energy of these electrons are highly dependent upon the strength of the magnetospheric convection, which is indirectly related to the (negative) magnitude of Dst. The dawnside peak in the X-ray images was equatorward of the LBHL peak, which was, in turn, equatorward of the LBHS peak. This is consistent with the electron energy dependence of these emissions, X-rays coming from the highest- and LBHS coming from the lowest-energy electrons.

The consistency of the imaging results with the particle measurements and the (electron) energy responses of the imagers and particle detectors clearly indicates that multispectral global images can be valuable for remotely sensing energetic auroral electron populations. The separation of particle data according to Kp, which is routinely used in operational space weather applications, gave little insight, but the observed correlation of the properties of the auroral oval with Dst is encouraging.

Anderson and Chen [2002] studied global auroral X-ray data from two isolated substorms and two substorms that occurred during magnetic storms. The X-ray emission patterns associated with isolated substorms differed from those associated with substorms taking place during storms. For the isolated substorms, emissions were initially seen at onset in the premidnight-to-midnight sector and then spread toward dawn. The emissions extended beyond 12:00 MLT, with the most intense emissions occurring in the postdawn sector. The time scales for the appearance of X-ray emissions in the morningside MLT sectors were consistent with the drift times of electrons, of sufficiently high energy to produce X rays detectable by PIXIE, under the influence of a magnetospheric electric field inferred from ionospheric ion-drift

measurements. During the recovery phase of the isolated substorms, the emissions died away gradually at increasing MLT, with the last of the emissions, in the noon sector, disappearing ~3-4 hours after substorm onset. During the stormtime substorms, emissions were seen in the premidnight-to-midnight regions at onset and spread toward dawn as in the isolated substorms. However, the emissions did not reach much beyond about 9 - 10 MLT, and very intense emissions were seen in the predawn MLT sectors. These intense predawn emissions were observed throughout the stormtime periods and were associated with significantly enhanced magnetospheric convection. There were brief reductions in intensity in the morningside emissions shortly after substorm onset, consistent with a brief reduction in the cross-tail electric field, followed by intensification again in the predawn sector on a time scale consonant with drifting electrons under the influence of a magnetospheric electric field. The authors concluded that the differences between the temporal evolution and morphology of the auroral X-ray emissions during isolated and stormtime substorms were the result of pitch-angle scattering mechanisms whose MLT distribution and intensity are dependent on the strength of the magnetospheric electric field.

McKenzie, *et al.*, [2002] have completed a multispectral analysis of auroral emissions during and after a substorm that occurred in the recovery phase of a magnetic storm on January 14, 1999. The analysis combined PIXIE X-ray spectral images, UVI LBHL and LBHS images, data from ground-based photometers stationed at Poker Flat and Fort Yukon, AK, and riograms from the HAARP riometer at Gakona, AK. The ground-based data were in the 03:00-04:30 MLT sector. The X-ray, UV, and ground-based photometer data were used to derive total incident auroral electron fluxes and average electron energies, and the riometer data provided insight into relatively low fluxes of high-energy electrons that were not otherwise discernible.

The parameters characterizing the incident auroral electrons were derived from the X-ray data alone, from the UVI data alone, and by a technique that used both *Polar* data sets. In most local time sectors, the average electron energies derived from the X-ray spectra were higher than those derived from the UVI LBHL/LBHS flux ratios. The incident electron energy flux and mean electron energy were derived by making a single fit to the observed X-ray spectrum, using an assumed generic spectral form (Maxwellian). With this technique the two derived parameters are not independently determined and are not independent of the assumed spectral form. In contrast, the LBHL flux provides a direct measure of the incident electron flux that is only weakly dependent upon the spectral shape. Once the incident electron flux is fixed, the total PIXIE detector counting rate is a sensitive function of the average electron energy, regardless of the spectral shape, provided that the average electron energy is less than about 15 keV. We then have a "two-photometer" technique that yields the parameters describing the incident electron population independent of the spectral shape. One photometer operates in the UVI LBHL band and the other measures the 2-11 keV X-ray flux. The average electron energies derived by the "two-photometer" technique agreed well with the PIXIE results, except near midnight MLT, where they were more in line with the lower energies derived from the LBHS/LBHL ratio.

Ground-based photometers deployed at Poker Flat and Fort Yukon, AK, derived total electron flux and average electron energy from spectral line measurements at 427.8, 630.0, 844.6, and 871.0 nm. The derived parameters agreed well with the UVI results, but the average energies derived from the X-ray spectra were slightly, but significantly, higher. Average energies from the UV/X-ray technique agreed well with those derived from the X-ray spectra alone. The HAARP imaging riometer at Gakona, AK, observed absorption above 2 dB during the period for which photometer data were available, with brief localized excursions as high as 4

dB. Such observations are indicative of a high-energy electron component that was not detected in the X-ray spectral analysis. When the PIXIE data were corrected for the presence of a high-energy electron component, the agreement among the three data sets improved significantly. This study illustrates the value of combining a large variety of observational data sets in order to characterize auroral electron populations.

References

Anderson, P. C., and M. W. Chen, "Examination of the storm/substorm relationship using global auroral X-ray images," *J. Geophys. Res.*, accepted for publication (2002).

Anderson, P. C., Petrinec, S. M., and K. Liou, "Statistical patterns in X-ray and UV auroral emissions and energetic electron precipitation," *J. Geophys. Res.*, **106**, 5907-5911, (2001).

McKenzie, D. L., J. H. Hecht, P. C. Anderson, G. A. Germany, T. J. Rosenberg, and D. J. Strickland, "Spectral analysis of auroral emissions from satellite and ground observations," in preparation, (2002).